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An Investigation of Several Methods for Predicting Post-Mining Spoils Water Quality From Overburden Extract in the Coal-Mining Area of Southeastern, Montana

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Overburden Extract in the Coal-Mining Area
of Southeastern, Montana

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Introduction

Several simplified, yet possibly adequate, methods have been employed for predicting post-mining water quality from overburden extract analyses. These techniques were developed as an alternative to extensive ground water and geochemical modeling. The first method considered was developed by Van Voast, et al; 1978. The other two methods considered were developed in conjunction with Hydrometrics by Systems Technology for the coal mining industry in southeastern Montana. All three methods have a similar theme: that of comparing overburden extract of a specified mined area to the observed spoils water quality. The key to developing a relationship between spoils water quality and overburden extract lies in finding a common entity. For example, in comparing streamflow data at two stations, the common entity is generally time. That is, stream flow data are grouped into pairs according to a similar occurance in time. For overburden extract and spoils water quality, location might be considered as a common entity. In fact, this approach was taken by Van Voast (1978); i.e., Decker and Big Sky mines.

The third method considered, termed the regression method, uses a more subtle common entity, that of specific conductance.

Data Evaluation

Two methods were employed to screen overburden extract and spoils water data to reject obvious error. The omission of bad data is a necessary step, since the predicting methods depend upon statistical relationships which can be significantly altered by inclusion of bad data due to the small sample sizes. The two screening techniques used were:

1. Cation-anion balance, and
2. Sum of cations versus specific conductance.

The cation anion balance technique (APHA, 1975) was applied to the spoils water data only, since anions are not analyzed in the overburden extract. A 10% difference was allowed in the sum of cations versus the sum of anions before data was rejected.

In both extract and spoils water quality, a strong linear relationship exists between the sum of cations and the specific conductance (U.S. Salinity Laboratory Staff, 1954). This relationship was used to reject extract data that was beyond the 95% confidence interval (2 standard deviations from the mean). Figure 1 shows a typical application of this screening for spoils water analyses in the Colstrip area.

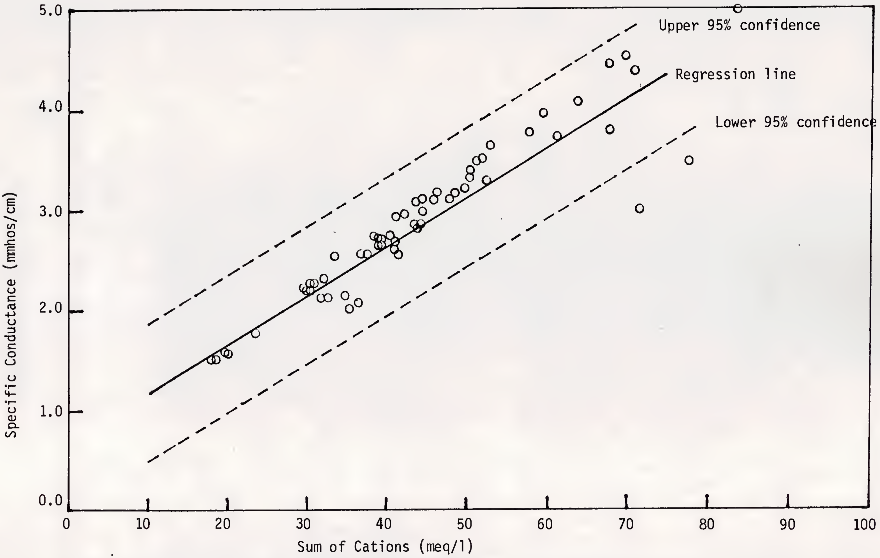


Figure 1:. Sum of Cations vs. Specific Conductance Screening Technique Applied to Spoils Water Data for the Colstrip Area

Methodology

1. Van Voast Method

As previously mentioned the Van Voast method uses location as a common entity. The variables related via the common entity are the 95% confidence limits about the log normal mean of the major cations (i.e. calcium, magnesium and sodium) for the spoils water versus the extract. Figures 2 thru 4 show the relationship developed by Van Voast. Since only two locations were considered a linear relationship was assumed. The procedure is to locate the anti-logs of the 95% confidence limits about the log normal mean for extract on the absissa (horizontal scale). Then proceed upward to the appropriate line (lower for lower limit; upper for upper limit) and over to the ordinate (vertical scale) to read the estimated anti-logs of the 95% confidence limits about the log normal mean for the spoils water.

Tables 1 thru 5 show the application of the Van Voast method to the extract at MONTCO. The extract data has been grouped by unit and depth. Zone 1 represents the first 20 feet of overburden. This zone generally has the highest concentration of constituents. Zone 2 represents the lowest 40' of overburden. The mining procedure proposed would seem to indicate that this zone of overburden would most likely become the saturated material associated with post-mining spoils water. Zone 3 represents all overburden down to the coal.

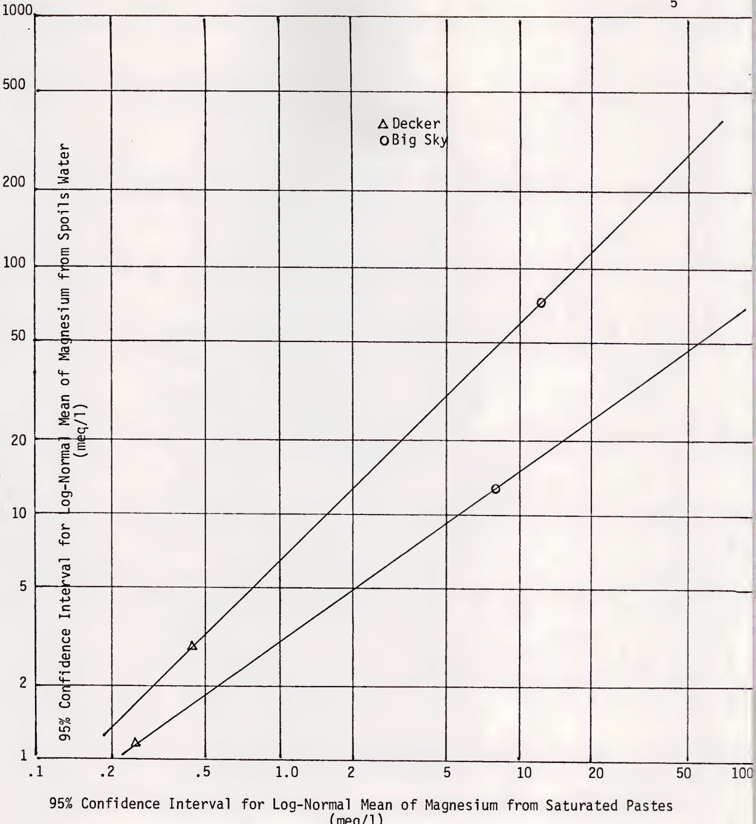


FIGURE 2. Nomograph Relating 95% Confidence Limits for Log Normal Mean of Magnesium in Extract to Spoils Water

Source: Van Voast, et al. 1978

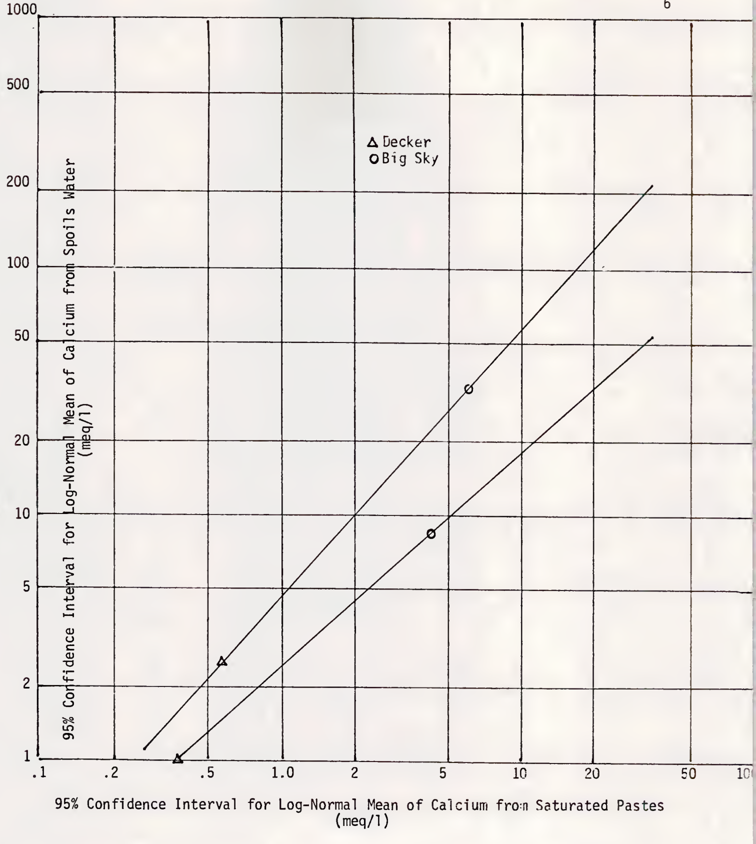


FIGURE 3: Nomograph Relating 95% Confidence Limits for Log Normal Mean of Calcium in Extract to Spoils Water

Source: Van Voast et al. 1978

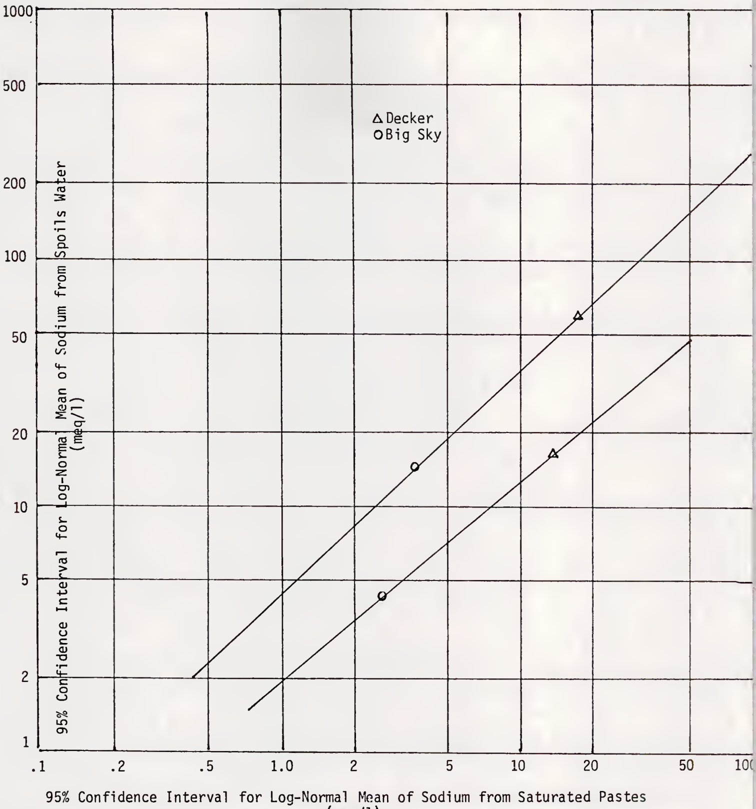


FIGURE 4: Nomograph Relating 95% Confidence Limits for Log Normal Mean of Sodium in Extract to Spoils Water

Source: Van Voast, et al. 1978

Table 1

Application of Van Voast Method to North King Unit
Log Cations in meq/l

Zone 1 (Overburden 0-20 feet)

Parameter	Mean of Logs	Stnd. Dev. of Logs	No. of Analyses	95% Confid. Interv. Lower	95% Confid. Interv. Upper	Est. Range Mean Spoils Water Concentrations Low	Est. Range Mean Spoils Water Concentrations High
Ca	0.72	0.61	67	3.75	7.35	7.40	39.5
Mg	1.07	0.56	67	8.63	16.0	13.5	94.0
Na	1.28	.69	67	13.0	27.9	16.0	95

Zone 2 (Overburden 40' above coal)

Ca	0.31	0.52	111	1.63	2.55	3.55	12.35
Ng	0.43	0.58	111	2.10	3.45	4.95	21.0
Na	1.41	0.28	111	22.80	28.98	24.5	98

Zone 3 (Overburden all depths)

Ca	0.4	0.56	332	2.19	2.88	4.6	14.2
Mg	0.67	0.60	332	4.03	5.43	7.8	32.5
Na	1.32	0.45	332	18.69	23.36	21.5	40.5

Table 2

Application of Van Voast Method to South King Unit
Log Cations in meq/l

Zone 1 (Overburden 0-20 feet)

Parameter	Mean of Logs	Stnd. Dev. of Logs	No. of Analyses	95% Confid. Interv. Lower	95% Confid. Interv. Upper	Est. Range Mean Spoils Water Concentrations Low	Est. Range Mean Spoils Water Concentrations High
Ca	.875	.640	16	3.64	15.4	7.2	90
Mg	1.181	.497	16	8.66	26.6	13.5	155
Na	1.493	.364	16	20.6	46.9	2.3	150

Zone 2 (Overburden 40' above coal)

Ca	.490	.409	24	2.12	4.50	4.5	23
Mg	.705	.418	24	3.45	7.45	7.0	45
Na	1.348	.295	24	17.0	29.2	20	100

Zone 3 (Overburden all depths)

Ca	.759	.523	109	4.58	7.20	9.0	39
Mg	.954	.483	109	7.30	11.1	12	66
Na	1.442	.258	109	24.8	30.9	27	105

Table 3

Application of Van Voast Method to North O'Dell Unit
Log Cations in meq/l

Zone 1 (Overburden 0-20 feet)

Parameter	Mean of Logs	Stnd. Dev. of Logs	No. of Analyses	95% Confid. Interv. Lower	95% Confid. Interv. Upper	Est. Range Mean Spoils Water Concentrations Low	Est. Range Mean Spoils Water Concentrations High
Ca	1.014	.275	4	5.55	19.21	10.5	113
Mg	1.522	.319	4	16.19	68.33	21.0	390
Na	1.855	0.169	4	48.91	104.9	47.5	7300

Zone 2 (Overburden 40' above coal)

Ca	.683	.445	8	2.37	9.80	4.90	54.5
Mg	.745	.395	8	2.96	10.44	6.3	85
Na	1.702	.132	8	40.79	62.15	40.5	198

Zone 3 (Overburden all depths)

Ca	.242	.886	27	0.81	3.77	1.90	18.5
Mg	.344	1.007	27	0.92	5.29	2.75	33.5
Na	1.595	.258	27	31.45	49.24	33.0	160

Table 4

Application of Van Voast Method to South O'Dell Unit
Log Cations in meq/l

Zone 1 (Overburden 0-20)

Parameter	Mean of Logs	Stnd. Dev. of Logs	No. of Analyses	95% Confid. Interv. Lower	95% Confid. Interv. Upper	Est. Range Mean Spoils Water Concentrations Low	Est. Range Mean Spoils Water Concentrations High
Ca	.231	.480	107	1.38	2.10	3.0	10
Mg	.316	.524	107	1.65	2.60	4.4	16
Na	1.525	.228	107	30.3	37.0	32	120
Zone 2 (Overburden 40' above coal)							
Ca	.976	.452	55	7.1	12.4	13	72
Mg	1.250	.453	55	13.5	23.4	18.5	140
Na	1.414	.556	55	18.4	36.6	21	120
Zone 3 (Overburden all depths)							
Ca	.380	.593	384	2.09	2.75	4.5	13.5
Mg	.543	.701	384	2.97	4.10	6.4	25
Na	1.483	.313	384	28.2	32.6	30	110

Table 5

Application of Van Voast Method to South Gate Unit
Log Cations in meq/l

Zone 1 (Overburden 0-20 feet)

Parameter	Mean of Logs	Stnd. Dev. of Logs	No. of Analyses	95% Confid. Interv. Lower	95% Confid. Interv. Upper	Est. Range Mean Spoils Water Concentrations Low	Est. Range Mean Spoils Water Concentrations High
Ca	.837	.510	54	5.02	9.40	9.6	52
Mg	1.009	.467	54	7.66	13.6	12.5	70
Na	1.42	.431	54	20.2	34.3	23	115

Zone 2 (Overburden 40' above coal)

Ca	.531	.494	171	2.86	4.03	5.8	20
Mg	.652	.478	171	3.81	5.29	7.5	32
Na	1.435	.236	171	25.1	29.5	27	100

Zone 3 (Overburden all depths)

Ca	.460	.558	391	2.54	3.28	5.3	16
Mg	.624	.526	391	3.73	4.74	7.5	28
Na	1.401	.310	391	23.5	27.0	26	92

2. Means and Variances Method

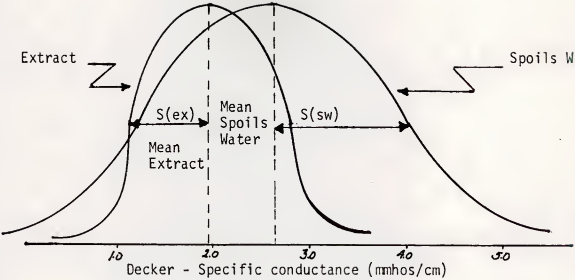
This method also uses location as the common entity. The means and variances of the extract and spoils water are the variables related at various locations. However, in this method no assumption is made regarding the relationship between locations.

Tables 6 and 7 show the mean ($\bar{x}$), standard deviation (s), and number of observations (n) of selected parameters for several locations for spoils water and extract respectively. Note that tables 1 through 5 presents the statistical summary of the various units at MONTCO. In addition, the extract data was confined to the lower depths adjacent to the coal.

For extract analyses comparisons are made between the various areas a T-test can be used to compare the difference of means. When a 1% risk level is used, one must be 99% confident that a difference exists between values before similarity is rejected. For example, the T-test analysis indicates statistical differences between the means of specific conductance for Big Sky, Colstrip and Decker. When compared, the various MONTCO units appear to be more comparable to Decker than Big Sky or Colstrip, so the relationship between extract and spoils water at Decker would be used.

The relationship is the ratios between the mean and variance of the extract, and the mean and variances of the spoils water. The graph in figure 5 shows the idea of this method.

The results of the application of this method to the various MONTCO units using the ratios for Decker spoils versus extract are displayed in tables 8 and 9. These give the estimated mean concentrations expected in the spoils water.



Conductivity Ratio of Means = X(sw)/X(ex) = 1.35

Conductivity Ratio of Variances = $S^2(sw)/S^2(ex)$ = 3.06

Mean Conductivity of N. King Overburden (40' abv coal) = 3.35 mmhos/cm

Variance Conductivity of N. King Overburden (40' abv Coal) = 1.77

Est. Mean Conductivity of N. King Spoils Water = 3.35 * 1.35 = 4.52 mmhos/cm

Est. Variance of N. King Spoils Water Conductivity = 1.77 * 3.06 = 5.42

Figure 5: Graphical Explanation of Mean & Variance Method

Table 6 Statistical Summary of Spoils Water Data

Specific Conductance (mmhos/cm)

	Big Sky	Decker	Colstrip
$\bar{x}$	3.40	2.68	2.89
s	1.35	1.40	0.80
n	74	15	57

Sodium (meq/l)

	Big Sky	Decker	Colstrip
$\bar{x}$	5.65	30.0	-
s	8.03	22.4	-
n	74	15	-

Table 7 Statistical Summary of Extract Data

	Big Sky	Decker	Colstrip	North King	South King	North O'Dell	South O'Dell	South Gate
				Specific Conductance (mmhos/cm)				
$\bar{x}$	-	1.98	1.97	3.35	3.48	5.55	3.84	3.59
s	-	0.80	2.07	1.33	1.72	1.61	1.33	2.78
n	-	44	2742	111	24	8	107	171
				Sodium (meq/l)				
$\bar{x}$	3.1	21.4	8.4	30.3	27.4	52.4	37.2	31.4
s	4.4	7.9	-	16.2	17.6	15.7	15.0	18.8
n	207	44	-	111	24	8	107	171

3. Linear Regression Method

Similar to the relationship between specific conductance and sum of cations, generally good linear relationships exist between individual cations and specific conductivity. In the analyses a correlation cut off of 0.80 was established as a measure of adequacy. That is, if a regression correlation was less than 0.80 the relationship was not considered strong enough for further analysis. Regression analyses were conducted for the various cations, sulfate and sum of cations versus specific conductivity for the spoils water data. However, in the overburden there was no analyses for sulfate. Tables 10 and 11 show the results of regression analyses for the extract and spoils water for several areas, for which the correlation was greater than .80. The results of the regression analysis on overburden extract for MONTCO are shown in table 12.

The relationship developed between extract and spoils water is again guided by location. However, the independent variable of similar regression analyses is used as a common entity. For example, by considering the sodium concentration versus specific conductivity as a common entity between the extract and spoils water, a matching is made between sodium in the extract and spoils water having the same specific conductivity where regressions have high correlations and small intercept values (i.e. $r > .80$; $b = 0$) the relationship between spoils water and extract becomes the ratio of slope (i.e. $a(sw)/a(ex)$). Figure 6 graphically displays this concept.

Table 8 Summary of Predicted Post-Mining Spoils Water Quality - Means & Variance Method for Sodium (meq/l)

Unit	Zone 1 $\bar{x}$	Zone 1 s	Zone 2 $\bar{x}$	Zone 2 s	Zone 3 $\bar{x}$	Zone 3 s
North King	57.4	111.5	42.7	48.6	44.4	34.7
South King	57.5	77.6	38.6	52.7	47.3	26.0
North O'Dell	106.9	87.5	73.3	47.2	67.3	37.9
South O'Dell	64.9	139.6	52.4	11.6	54.5	37.3
South Gate	57.3	114.5	44.3	56.3	47.2	40.4

(Columns grouped under the spanning heading "Estimated Constitutent Concentration".)

Table 9 Summary of Predicted Post-Mining Spoils Water Quality - Means & Variance Method for Specific Conductance [1]

Estimated Constituent Concentration

Unit	Zone 1 $\bar{x}$	Zone 1 s	Zone 2 $\bar{x}$	Zone 2 s	Zone 3 $\bar{x}$	Zone 3 s
North King	6.90	6.63	4.52	2.33	5.1	2.55
South King	7.68	5.76	4.70	3.00	6.32	2.40
North O'Dell	13.5	7.2	7.49	2.74	7.33	3.79
South O'Dell	8.28	7.48	5.18	2.01	5.95	2.75
South Gate	9.05	8.82	4.85	4.85	6.21	3.96

Notes: 1. Specific Conductance in millimhos/cm

Table 10 Summary of Regression Analysis on Extract Data From Colstrip and Decker

	Decker*	Colstrip[1]
	SC = a (Calcium + Magnesium + Sodium) + b	
Slope (a)	0.079	.070
Intercept (b)	+0.17	+.26
Correlation (R^2)	0.92	.94
Standard Error (se)	0.23	.31
Number of Obser. (n)	57	1194
	Na = a(sc) + b	
Slope (a)	9.02	-
Intercept (b)	3.3	-
Correlation (R^2)	0.88	-
Standard Error (se)	2.71	-
Number of Obser. (n)	57	-

*Decker regression is based on samples deeper than 70 feet.

Notes: 1. The Na vs SC regression for the Colstrip area had an $r < .80$ and in the Colstrip area Na is not the dominant cation as it is at Decker and MONTCO.

2. Cations are in meq/l, Specific Conductance is in millimhos/cm

Table 11 Summary of regression Analysis on Spoils Water From Colstrip and Decker

	Decker	Colstrip
	SC = a (Calcium + Magnesium + Sodium) + b	
Slope (a)	0.081	.05
Intercept (b)	0.12	+.62
Correlation (R^2)	0.99	.96
Standard Error (se)	0.15	.3
Number of Obser. (n)	16	67
	Na = a(sc) + b	
Slope (a)	11.30	-
Intercept (b)	0.27	-
Correlation (R^2)	0.99	-
Standard Error (se)	2.16	-
Number of Obser. (n)	15	-

Note: Cations are in meq/l, Specific Conductance is in millimhos/cm

Table 12 Summary of Regression Analysis
for Overburden Extract at MONTCO
Na = a(sc) + b

Unit		Slope (a)	Intercept (b)	Correlation (r^2)	Stnd. Error (se)	No. Obs. (n)
North King	Zone 1	9.17	+ 6.1	0.88	-	67
	Zone 2	10.13	+ 3.7	0.69	-	111
	Zone 3	8.93	- 2.2	0.81	-	332
South King	Zone 1	7.25	- 0.4	0.85	10.3	16
	Zone 2	9.08	- 4.1	0.79	8.5	24
	Zone 3	6.45	+ 3.0	0.67	9.9	109
North O'Dell	Zone 1	7.05	+ 5.5	0.99	3.7	4
	Zone 2	9.05	+ 2.2	0.85	6.5	8
	Zone 3	7.12	+ 8.5	0.96	5.4	27
South O'Dell	Zone 1	10.23	-16.7	0.88	15.9	55
	Zone 2	9.50	+ 0.7	0.71	8.1	107
	Zone 3	8.79	- 0.3	0.79	11.4	386
South Gate	Zone 1	5.58	+ 3.2	0.55	26.0	54
	Zone 2	2.78	+21.4	0.17	17.2	171
	Zone 3	4.38	+12.7	0.34	21.7	391

Note: Sodium is in meq/l, Specific Conductance is in meq/l

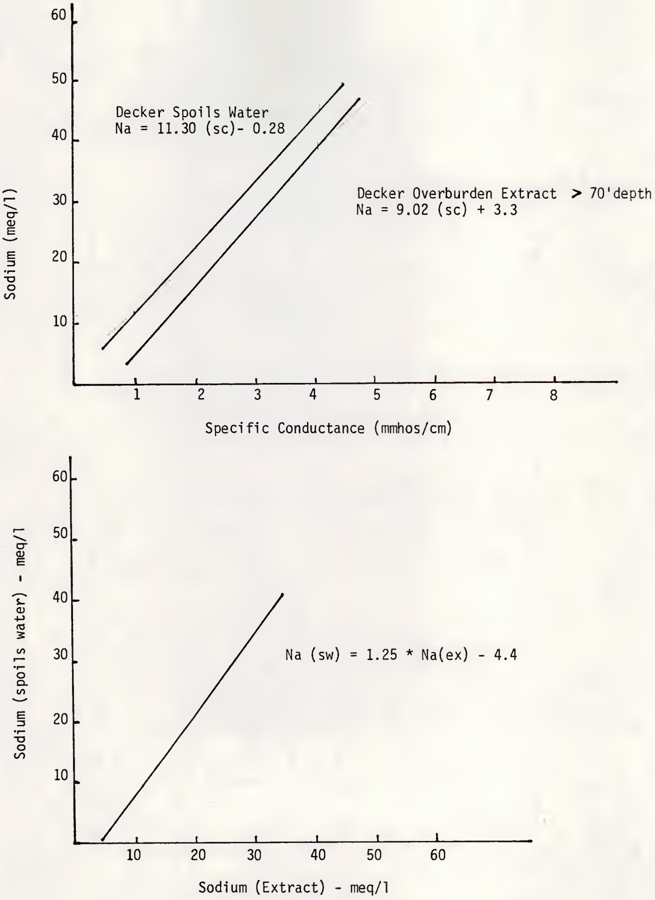


Figure 6: Graphical Explanation of Linear Regression Method

The mean and variance method described previously determines a shift in the concentration from extract to spoils water. The ratio of slopes between extract and spoils water determines a shift in the relative proportion of the ions. The regression method combines these two measures of change to estimate post-mining spoils water quality. The results of the linear regression method applied to the various units of MONTCO are shown in Table 13.

Table 13 Summary of Predicted Post-Mining Spoils Water Quality - Linear Regression Method

Unit	Zone 1 SC	Zone 1 Na	Zone 2 SC	Zone 2 Na	Zone 3 SC	Zone 3 Na
	Estimated Constituent Concentration					
North King	-	87.1	-	57.3	-	45.6
South King	-	87.2	-	53.3	-	41.1
North O'Dell	-	153	-	84.9	-	52.6
South O'Dell	-	98.3	-	61.5	-	52.5
South Gate	-	31.4	-	16.8	-	27.3

Note: Sodium is in meq/l

Comparison of Results

Table 14 compares the mean and variance method with the Van Voast method. The Van Voast method generally predicts a higher 95% confident unit than the means and variance method. Since the concern is on how high the concentrations of salts may become in the spoils water, the upper unit is of more importance than the lower limit. This situation may be a result of the use of logrithms. Logrithms will tend to shift the data such that the lower 95% confidence limits are never zero or negative.

The results of the mean and variance method and linear regression method are compared in table 15. Since the linear regression method provides a refinement to the mean and variance method it is not surprising that they compare favorably. This is especially true when the ratio of slopes is approximately unity, indicating all the shift to be due to magnitude rather than the relative proportion of the ions.

Table 14 Comparison of the Results From the Van Voast and Mean and Variance Methods for Sodium 1)

Unit		Van Voast Lower 95%	Van Voast Upper 95%	Means & Variance Lower 95%	Means & Variance Upper 95%
North King	Zone 1	21.5	80	0.9	113.8
	Zone 2	24.5	98	18.1	67.3
	Zone 3	21.5	80	26.8	62.0
South King	Zone 1	23	150	18.2	96.8
	Zone 2	20	100	11.4	65.8
	Zone 3	27	105	40.6	54.0
North O'Dell	Zone 1	47.5	300	62.6	151.2
	Zone 2	40.5	198	48.9	97.7
	Zone 3	33	160	48.1	86.5
South O'Dell	Zone 1	21	120	- 5.7	135.5
	Zone 2	32	120	46.5	58.3
	Zone 3	30	110	54.5	73.4
South Gate	Zone 1	23	115	- 0.6	115.2
	Zone 2	27	100	15.8	86.6
	Zone 3	26	92	34.5	59.9

Note: Sodium is in meq/l

Table 15 Comparison of Estimated Mean Sodium in meq/l for Spoils Water at MONTCO Units

Units	Zone 1		Zone 2		Zone 3	
	Mean & Var.	Lin. Reg.	Mean & Var.	Lin. Reg.	Mean & Var.	Lin. Reg.
North King	57.4	87.1	42.7	57.3	44.4	45.6
South King	57.5	87.2	38.6	53.3	47.3	41.1
North O'Dell	106.9	153	73.3	84.9	67.3	52.6
South O'Dell	64.9	98.3	52.4	61.5	54.5	52.5
South Gate	57.3	N/A*	44.3	N/A	47.2	N/A

*Method of Linear Regression not applicable to South Gate Unit because of poor correlations (R^2 - 0.55 or less).

A Summary of Several Methods for Predicting
Spoils Water Quality From Overburden Extract Data

Several simplified, yet possibly adequate, methods have been investigated for predicting post-mining spoils water quality from overburden extract analyses. These techniques were developed as an alternative to extensive groundwater and geochemical modeling.

The basic assumption is that the overburden extract chemistry is an indicator of the resultant spoils water quality. Employing this assumption, statistical relationships are investigated which provide a link between the extract and spoils water. The key to developing this relationship between spoils water quality and overburden extract lies in finding a common entity.

In the technique developed by Van Voast et al. (1978), location is the common entity. The 95% confidence limits of the dominant cations for the extract and spoils water were matched at a given location. Because of limited data, the Van Voast technique only develops two locations (i.e. Decker and Big Sky mines). A further assumption made in the Van Voast technique is that a linear relation exists between the locations.

In the two techniques investigated by System Technology (1982), one uses location as the common entity, whereas the other uses a more subtle common entity, that of specific conductance. The "means and variance" technique, like that of Van Voast, matches a statistical parameter of one data set (e.g. extract) with the same statistical parameter of another data set (e.g. spoils water). The statistical parameters compared between the extract and spoils water at the various locations are the mean and variance. Data were analyzed at three locations; Big Sky, Colstrip and Decker. However, in this method no assumption is made regarding the relationship between locations. To use the method, the extract for a location whose spoils water quality is to be estimated is compared to the extract at one of the three

locations. The comparison between extract at the locations is made using a T-test for the means. When a 1% risk level is used, one must be 99% confident that a difference exists between values before similarity is rejected. For example, the T-test analysis indicated statistical differences between the means of specific conductance for Big Sky, Colstrip and Decker. When compared, the various MONTCO mining units appear to be more similar to Decker than to Big Sky or to Colstrip. Thus, the relationship between extract and spoils water at the Decker location is used as an analog to the MONTCO area.

In the "linear regression" technique, the independant variable of similar regression analyses is used as the common entity. For example, good linear regressions exist for sodium versus specific conductance in both the extract and spoils water at Decker. By considering the specific conductance as a common entity between the extract and spoils water, a matching is made between sodium in the extract and spoils water. Linear regressions were developed at the various locations. A correlation of 0.80 or greater was used to establish adequacy of the relationship. To use the technique, the cation versus specific conductance relationships for the extract of a location whose spoils water quality is to be estimated is compared to similar relationships at one of the three known locations. The comparison of extract relationships at the various locations can be based upon a T-test analysis of means or slopes of the regression equations. When using the slopes as a guide, the intercept values (i.e. the regression constants) should be small (i.e. approximately zero). As with the "mean and variance" technique, the various MONTCO units show more similarity to Decker than to the Big Sky or Colstrip mines.

Whereas the Van Voast and mean and variance methods indicate (measure) the shift in the magnitude of the concentration from extract to spoils water, the linear regression technique indicates a shift in the relative preparations of the cations. The results of the application of these techniques are shown in the following tables.

References Cited

Systems Technology, 1982, "An Investigation of Several Methods for Predicting Post-Mining Spoils Water Quality from Overburden Extract in the Coal-Mining Area of Southeastern Montana," unpublished report to Montana Department of State Lands, 28 p.

Van Voast, W. A., R. B. Hedges, and J. J. McDermott, 1978, "Strip Coal Mining and Mined-Land Reclamation in the Hydrologic System, Southeastern Montana," Project Completion Report of OWRC Grant No. 10570165, Old West Regional Commission, Billings, MT., 122 p.

Comparison of the Results From the Van Voast and Mean and Variance Methods for Sodium in meq/l.

Unit		Van Voast Lower 95%	Van Voast Upper 95%	Means & Variance Lower 95%	Means & Variance Upper 95%
North King	Zone 1	21.5	80	0.9	113.9
	Zone 2	24.5	98	18.1	67.3
	Zone 3	21.5	80	26.8	62.0
South King	Zone 1	23	150	18.2	96.8
	Zone 2	20	100	11.4	65.8
	Zone 3	27	105	40.6	54.0
North O'Dell	Zone 1	47.5	300	62.6	151.2
	Zone 2	40.5	198	48.9	97.7
	Zone 3	33	160	48.1	86.5
South O'Dell	Zone 1	21	120	-5.7	135.5
	Zone 2	32	120	46.5	58.3
	Zone 3	30	110	54.5	73.4
South Gate	Zone 1	23	115	-0.6	115.2
	Zone 2	27	100	15.8	86.6
	Zone 3	26	92	34.5	59.9

Note: Sodium is in meq/l

Zone 1. represents the first 20 feet of overburden

Zone 2. represents the 40 feet of overburden above the coal

Zone 3. represents all overburden down to the coal

Comparison of Estimated Mean Sodium in meq/l
for Spoils Water at MONTCO Units

Units	Zone 1 Mean & Var.	Zone 1 Lin. Reg.	Zone 2 Mean & Var.	Zone 2 Lin. Reg.	Zone 3 Mean & Var.	Zone 3 Lin. Reg.
North King	57.4	87.1	42.1	57.3	44.4	45.6
South King	57.5	87.2	38.6	53.3	47.3	41.1
North O'Dell	106.9	153	73.3	84.9	67.3	52.6
South O'Dell	64.9	98.3	52.4	61.5	54.5	52.5
South Gate	57.3	N/A*	44.3	N/A	47.2	N/A

*Method of Linear Regression not applicable to South Gate Unit because of poor correlations (R^2 = 0.55 or less).